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Macronutrients for Plants Growth and Humans Health

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ABSTRACT

Macronutrients are crucial for the growth, and development of plants due to their roles as structural components and redox-sensitive agents. Generally, the application of macronutrients leads to increased crop output, growth, and overall quality. While macronutrients play a role in every stage of a plant's life, scientists in fields such as plant physiology, biotechnology, and eco-physiology have recently focused on exploring additional aspects of these minerals, and their potential. Each macronutrient has a unique function in plant metabolism, and this study aims to examine the latest advancements in understanding the specific roles of macronutrients in plant growth and acclimatization. Furthermore, the study also discusses future research prospects in this field, highlighting the importance of ongoing investigations in maximizing plant productivity, and resilience.

Keywords- Plants, Humans, Macronutrients, Growth, Deficiency.

I. INTRODUCTION

Plants are living entities that require certain nutrients to grow, and thrive, including macronutrients and micronutrients (Delgado, A., et al. 2023, Wiedenhoeft, A. C. 2006), macronutrients are necessary nutrients that plants require in relatively high amounts to carry out vital physiological functions including photosynthesis, respiration, and growth (Candanosa, R. M. 2017). Nitrogen, phosphorus, and potassium are major macronutrients (Daramola, D. A., & Hatzell, M. C. 2023), whereas calcium, magnesium, and sulfur are minor macronutrients (Hawkesford, M. J., et al. 2023). Plants require particular nutrients to grow and thrive, including macronutrients (which are required in greater quantities) and micronutrients (Diwakar, A. K., et al. 2023). The principal macronutrients are nitrogen, phosphorous, and potassium, while minor macronutrients include calcium, magnesium, and sulfur (Abbas, F., et al. 2023), these macronutrients are required in large quantities by plants to carry out essential physiological processes such as photosynthesis, respiration, and growth, and maintaining a balanced supply of these nutrients in the soil is essential for healthy plant growth (Karthika, K. S., et al. 2018). Secondary macronutrients, such as calcium, magnesium, and sulfur, are also essential (Keita, D. S., et al. 2023). Plant physiologists, molecular biologists, and agronomists are all interested in the study of plant mineral nutrients because of their role in plant growth, development, and yield (Basu, U., & Parida, S. K. (2023). Numerous research has focused on the importance of various chemical components and compounds for plant development, as well as their functions in external activities and metabolism (Abdelsattar, A. M., et al. 2023). In the nineteenth century, the essential elements of nitrogen, phosphorus, sulfur, potassium, calcium, magnesium, and iron were

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discovered. In 1972, Epstein defined elemental necessities as essential or non-essential (Marschner, H. (Ed.), 2011).

There are 20 elements that are needed or advantageous to plant existence (Kirkby, E. A. 2023), including three primary elements, carbon, hydrogen, and oxygen, which are absorbed by air and water (Yin, R., et al. 2023), the remaining components are absorbed from the soil by plant roots (Kirkby, E. A. 2023), these elements have been classed as macronutrients (nitrogen, phosphorus, potassium, calcium, and magnesium) and micronutrients (B, Cl, Cu, Fe, Mo, Mn, Ni, Na, and Zn). Silicon, and cobalt are thought to be useful but not necessary for all plants (Mushtaq, N. U., et al. 2023).

Malnourishment is still pervasive in many regions of the world, despite the fact that the human body requires 22 mineral components for proper health (Islam, M., et al. 2023). Due to the scarcity of minerals in natural sources, calcium, magnesium, and copper shortages are widespread in developed and developing countries (Singh, S. K., et al. 2023), studies on the process of element translocation, and molecular dynamics within plant cells have received a lot of attention in recent years (Saha, B., et al. 2023, Mustafa, A., et al. 2023).

II. MACRONUTRIENTS

Macronutrients are vital for both plant, and human existence since they execute multiple metabolic activities (Tariq, A., et al. 2023). There are two types of nutrients: major macronutrients N, P, and K, and secondary macronutrients Ca, Mg, and S, (Golden, M. H. 1995, Chathyushya, K. B., et al. 2023), they serve an important function in plant metabolism, defending plants against diverse stressors, and enhancing crop output, growth, and quality (Kumar, S., et al. 2023). Researchers have been studying the various roles of these nutrients in plant life and their future possibilities in recent years (Jacoby, R., et al. 2017), each macronutrient has a distinct personality, and participates in many metabolic pathways in plant life, the information in the table is based on estimations, and may change depending on the source (Kumari, S., et al. 2023), the year an element was found relates to its discovery as an element, not necessarily its discovery in nature, table 1, (Murphy, P. J. 2011).

2.1 Primary Macronutrients

2.1.1 NITROGEN

Nitrogen, the 15th element of the periodic table, belongs to the P block, it was first identified in 1772 by Daniel Rutherford, and named "nitrogen" by Jean-Antoine Chaptal in 1790 (Leghari, S. J., et al. 2016). Nitrogen is largely found in the earth's atmosphere, accounting for 78.09% of the total amount, and exists as a colorless, and tasteless gas, it is a vital component of plants, accounting for 1.5-2.0% of plant dry matter and 16% of total plant protein (Stein, L. Y., & Klotz, M. G. 2016, Chen, B., et al. 2023).

Nitrogen, the sixth most abundant element in our solar system, is also required by all current cells, it is a necessary component of all proteins and enzymes and is involved in the metabolic processes of energy transformation (Jackson, P. J., et al. 2023), nitrogen supply affects plant growth, fruit, and seed yield, forage crop quality, and leaf development, all of which are important for agricultural productivity (Saha, B., et al. 2023). In natural ecosystems, and agriculture, nitrogen exists in a range of forms, including nitrate, nitrite, ammonium, and amino acids (Liu, J., et al. 2023), plants instantly take nitrogen from various sources, including fertilizers, air, water, rain, and molecular form (N2), (Mahboob, W., et al. 2023), soil organisms transform nitrogen into numerous useful forms (Karabulut, F., et al. 2023), agricultural output has more than quadrupled in the last 50 years due to the extensive use of nitrogen fertilizer; yet, industrial pollution, and dramatic climate change have had a substantial impact on the natural nitrogen cycle (Osei, E., et al. 2023).

Plants have evolved intricate physiological and morphological responses to varied patterns of nitrogen supply in order to manage their development and growth, the effect of nitrogen on the metabolism of essential and non-essential amino acids has been studied (Wevar Oller, A. L., et al. 2023), Nitrogen supply affects plant hormonal state, and phytohormones such as abscisic acid (ABA), indole-3-acetic acid (IAA), and cytokinins (CK) are strongly connected to nitrogen signaling (Joshi, H., et al. 2023), Nitrogen availability is tightly associated with cytokinins in many plant species, and cytokinin metabolism and translocation are influenced by nitrogen nutritional status (Ahmad, N., et al. 2023). Research has focused on nitrogen fixing, and nitrogen absorption including genes, genetic, biochemical, and ecological issues, and future possibilities in sustainable agricultural growth (Alam, I., et al. 2023). Nitrogen deficiency symptoms vary by plant type, but frequent symptoms include stunted growth, yellowing of older leaves, and decreased yields; in extreme cases, plants may even die, plants require adequate nitrogen for proper growth and development, table 2, (Rosen, C., et al. 2023).

2.1.2 PHOSPHORUS

Phosphorus is a nonmetallic element that belongs to the periodic table's P block and was discovered in 1669 by Joseph Priestley, but Antoine Lavoisier did not recognize it as an element until 1777 (Childs, P. E. 1998). Phosphorus comes in two forms: white P and red P; nevertheless, due to its high reactivity, it is not generally available as a free component on Earth; as a result, its derivatives are largely used in the production of fertilizers, detergents, pesticides, and matches (Desmidt, E., et al. 2015).

Phosphorus, which is abundant in plant cell membranes as phosphate, is required for plant growth

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and development as a component of DNA, RNA, and ATP; however, its availability in the soil is frequently limited, necessitating the use of large amounts of organic phosphate exogenously to achieve high crop yields; fertilizers are used by approximately 46% of barley and wheat plants (Malhotra, H., et al. 2018). The fast depletion of nonrenewable P resources caused by extensive P fertilization in crop fields contributes to the pollution of the environment, a shortage of it in the soil, on the other hand, greatly affects crop yields; as a result, experts researching agronomy and agriculture do research on different aspects of P intake, absorption, and its impact on various metabolic processes (Roy-Bolduc, A., & Hijri, M. 2011).

Phosphate transporters (PTs) are enzymes that aid in the absorption, and transport of inorganic phosphate in the soil. (Pi). In rice, the Pht1 family's PT gene OsPht1 is prominently involved in P homeostasis; in Brassica rapa, regulatory hotspots are similarly linked to plant gene expression under fluctuating soil P availability (Młodzińska, E., & Zboińska, M. 2016). The production of low-affinity PTs and non-coding RNA, IPS1, has been connected to P consumption efficiency in barley (Gu, M., et al. 2016), furthermore, reduced P availability in root cortical parenchyma increases maize plant growth via modifying cell division or cell elongation factors (Prathap, V., et al. 2022), leaf growth depression induced by P deficiency is well-known, resulting in a reduction in cell division and cell elongation in many grass species' leaves (Broadley, M., et al. 2012). Phosphorus is an essential component of photosynthetic activity, aiding in the conversion of solar energy into chemical energy, proper plant growth, and stress tolerance (Kruse, O., et al. 2005), it also promotes the rapid growth of plants and root systems, necessitating more research on P availability and consumption from an agronomical, agro-economical, and agricultural viewpoint (Schoumans, O. F., et al. 2104), the phosphorus percentage changes depending on plant species and development stage, table 3, (Aydin, I., & Uzun, F. 2005).

2.1.3 POTASSIUM

Potassium is essential for plant growth, and development because it improves photosynthesis, enzyme activation, water relations, assimilates, transportation, and overall growth and development (Oosterhuis, D. M., et al. 2014), Potassium is an alkaline and highly reactive chemical element with the atomic number 19, and its symbol (K), is derived from the Neo-Latin word (kalium), Potassium was discovered by Humphry Davy in 1807, and it is a vital and highly mobile macronutrient present in plants' juvenile parts and cytoplasm, plants cannot live in the absence of potassium (Mohammed, N. A. 2016).

Potassium is also involved in the production of proteins, which is essential for transcription and translation, as well as the binding of transfer RNA (tRNA) to ribosomes, because of the vulnerability of plant cell membranes to K ions, K ions are engaged in the control of several cell processes (Pozharskii, A. F., et al. 2011), Potassium is also involved in the stimulation of the generation of nicotinamide adenine dinucleotide phosphate (NADPH), which is needed for photosynthesis, because K is actively involved in the movement of metabolites, minerals, phytohormones, and water through the xylem and phloem, deficiencies in Potassium ions have a substantial impact on these transportation systems (Kumari, A., et al. 2015), Potassium aids in the stability of pH and the diffusion of different organic anions and other chemicals inside the plant, the process of opening and shutting stomata in plants is reliant on Potassium ions, which helps to decrease water loss and the danger of drought stress (Raschke, K. 1975).

Potassium is critical in minimizing global agricultural and agronomic challenges such as heavy metal stress (Elango, D., et al. 2022), Excess potassium, on the other hand, can be harmful and even fatal, causing hyperkalemia in the blood, which can lead to muscular weakness, irregular pulse, and, in extreme cases, cardiac arrest (Pohl, H. R., et al. 2013). Plant cell membranes are relatively permeable to K ions due to the presence of several selective K ion channels and are thus engaged in the regulation of many cell activities (Hedrich, R. 2012), the amount of K in the cytosol is highest, i.e., 30–50 mM, while 20 mM is found in the vascular region of the cells (Nover, L. U. T. Z., et al. 1989), it is important to note that the specific levels of potassium in different plant portions may vary depending on the species, growing conditions, and stage of growth (Collins, A., et al. 2023). Deficiency symptoms may also manifest differently based on various factors (De Vries, W., et al. 2014), however, in general, potassium deficiency can lead to lower plant growth, productivity, and quality, as well as increased sensitivity to various stresses and diseases, table 4, (Amtmann, A., et al. 2008).

2.2 Secondary Macronutrients

2.2.1 CALCIUM

Calcium is a chemical element with the symbol (Ca) and atomic number 20 that belongs to the periodic table's second group and S block (Frieden, E. 1972). Among all accessible elements, calcium is the fifth most plentiful element in the earth's crust and the fifth most prevalent liquid ion in the ocean (Aversa, R., et al. 2016). Humphry Davy discovered calcium in 1808, and it is one of the most vital elements for all living things, particularly in the form of calcium ions (Ca2+), which facilitate and participate in numerous cellular activities (Forsen, S. T. U. R. E., & Kordel, J. O. H. A. N. 1994).

By activating enzymes, causing water flow, and salt balance in plant cells, and activating K to control the process of stomatal opening and closing, calcium is essential for plant growth and development (Hasanuzzaman, M., et al. 2018), it also plays an important role in cell growth, division, elongation, and other vital biological processes, such as increasing

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nutrient intake, enhancing plant tissue resistance, strengthening cell walls, and contributing to optimal root system development (Farooq, M., et al. 2009, Ozturk, H., et al. 2023).

Ca2+ is sharply transported from the cytosol into the mitochondria, endoplasmic reticulum, cell walls, plastids, and vacuoles as a result of the development of several mechanisms for tightly managing calcium ion (Ca2+) fluxes and different Ca pools (Raven, J. A. 2023, Corti, F., et al. 2023, Hong-Bo, S., et al. 2008). Ca2+/H+ antiporters, Ca2+-ATPases, and other helpful signaling channels minimize ionic stress in plants and protect them from biotic and abiotic problems, finally, Ca porous ion channels are important for drought stress signal transduction (de Freitas, Sergio Tonetto, and Elizabeth J. Mitcham. 2012). According to current research, the SlSRs gene responds to a range of stress signals and may function as a coordinator, integrating Ca-mediated signaling with other stress signal transduction pathways during fruit ripening and storage (Tripathi, D. K., et al. 2014), in addition, during NaCl stress, a gene known as HSP efficiently expressed Ca signaling pathways in tobacco (Rizhsky, L., et al. 2002, Li, M., et al. 2014). Resistance to a number of abiotic and biotic stresses, most notably drought, cold, pathogens, and wounding (Golebiowska-Paluch, G., & Dyda, M. 2023), as well as ethylene, auxin, MeJA, and SA, is enhanced by SR/CAMTA and other transcription factors (Yang, T., et al. 2013, Li, X., et al. 2014).

Calcium is also essential in the human body for bone and tooth formation, and maintenance, muscle function, nerve function, blood coagulation, and cell signaling (Buchowski, M. S. 2015), there are plenty of dairy products, leafy greens, fortified meals, and supplements (Miller, G. D., et al. 2001, Graham, M., et al. 2023), however, too much or too little calcium in the body can create health problems, so maintaining a healthy balance is crucial (Quattrini, S., et al. 2016, Mohammadnezhadostad, F., et al. 2023).

Plant growth and development require calcium, it is essential for a variety of cellular functions in plants, including root system growth, cell wall formation and stability, enzyme activation, stomatal regulation, and fruit production (Waraich, E. A., et al. 2011, Niazi, P., et al. 2023), the roots contain the most calcium, followed by the leaves, stems, flowers, and fruits (Bhattarai, S. P., et al. 2006), Calcium deficiency can cause stunted plant growth, weak stems, poor fruit set, and uneven leaf production, among other symptoms, a healthy calcium intake is critical for plant growth and development (Uchida, R. 2000, Ray, P. K. 2023), and also Calcium deficiency produces yellowing and black areas on leaves, and it is immobile when deposited in plant tissues, table 5, (Mihai, R. A., et al. 2023).

2.2.2 MAGNESIUM

Magnesium is an alkaline earth metal that is the eighth most prevalent element in the Earth's crust and the ninth most abundant element in the universe (Ledda, C., & Fiore, M. 2013, Ahmed, M. E., et al. 2023) It was discovered by Joseph Black in 1755 and isolated by Humphry Davy in 1808 (Pathan, M. F. 2022, Webb, S. 2023). Magnesium is found in all living things on Earth, and has a range of helpful tasks in addition to being one of the fundamental nutritional components for survival (Duruibe, J. O., et al. 2007), it accounts for 0.2-0.4% of dry matter in plants and has a need of 1.5-3.5 g kg-1 for excellent plant development in the vegetative zones (Williams, C. J., & Yavitt, J. B. 2003), Magnesium is an important component of chlorophyll and is required for plant photosynthesis (Cakmak, I., & Yazici, A. M. 2010). Very small changes in magnesium levels can affect a number of essential chloroplast enzymes (Amareh, R., et al. 2023), and research indicates that magnesium is an active component of the electron transport chain (Huxley, H. E. 1969), furthermore, enough magnesium content increases the activity of anti-oxidative enzymes as well as the number of antioxidant molecules (Liao, Z., et al. 2019).

Magnesium is essential for the proper functioning of the human body, and is involved in several biological processes, including bone and tooth growth, DNA synthesis, energy metabolism, nerve and muscle function, and many more (Soetan, K. O., et al. 2010), its deficiency can cause a range of health problems, including muscle cramps, seizures, and abnormal heart rhythms; thus, it is vital to maintain an adequate amount of magnesium in the body through a well-balanced diet or supplements (Hallfrisch, J., & Muller, D. C. 1993, Gleeson, M., et al. 2004).

Magnesium deficiency symptoms in plants include yellowing or browning of leaves, particularly between the veins (interveinal chlorosis), stunted growth, and reduced seed production; these symptoms may appear in different parts of the plant depending on the severity and duration of the deficiency ((Uchida, R. 2000, Wang, Y., et al. 2023, McCauley, A., et al. 2009, Das, S. K., et al. 2017), Magnesium deficiency induces oxidative stress in plants, whereas enough magnesium activates the antioxidant machinery (Tränkner, M., et al. 2016). Magnesium aids rice and other plant species in dealing with stress and heavy metal stress, and it also plays a significant role in disease resistance management in various plant species, table 6, (Moustafa-Farag, M., et al. 2020).

2.2.3 SULFUR

Sulfur (S), the sixteenth element in the periodic table, occurs naturally in sulfide and sulfate minerals and is abundant in the Earth's crust; it has an atomic weight of 32.06, and was discovered in China around 2000 BC before being identified as an element by Antoine Lavoisier in 1777 (Brosnan, J. T., & Brosnan, M. E. (2006); Sulfur is an important plant nutrient that is required for the formation of chlorophyll, proteins, seed oil, and amino acids such as methionine, and cyst (Traber, M. G., & Cross, C. 2023, Shah, S. H., et al. 2022)

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Volume-2 Issue-2 || April 2023 || PP. 268-279
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Sulfur is frequently employed in the manufacturing of sulfuric acid, which is one of the most widely used industrial chemicals (Kutney, G. (2023). Sulfuric acid is used to make fertilizers, dyes, detergents, and a variety of other items, it is also used to recover metals from ores in the mining sector, and Sulfuric acid is extremely corrosive and must be handled with extreme caution (Shekade, S. V., et al. 2023, Ramesh, B. et al. 2023). Sulfur is also used in the production of sulfur dioxide, a major air pollutant (Xu, Q., et al. 2023). Sulfur dioxide, a key component of acid rain, is produced by the combustion of fossil fuels such as coal and oil, acid rain can damage trees, lakes, and structures, as well as pose a threat to human health, while several countries have made progress in reducing sulfur dioxide emissions, more needs to be done to address this issue (Liu, C., et al. 2023, Wan, Z., et al. 2023, Jha, S., & Yadav, A. 2023, Weng, W., et al. 2023).

Sulfur is an essential component of agricultural plants since it is required for the formation of amino acids, which serve as the building blocks of proteins (Ali, V., et al. 2023), Sulfur also contributes to the formation of chlorophyll, which is essential for photosynthesis Freire, M. Á. 2023)., Sulfur is a common soil fertilizer, and it is especially important for crops like onions, garlic, and cruciferous vegetables like broccoli and cauliflower (Castro, V., et al. 2023). Sulfur is also used in the production of rubber, which is an important industrial commodity, Sulfur is added to rubber during the vulcanization process, which boosts its strength, flexibility, and durability (Yamano, A., et al. 2023), Sulfur has a long history of use in medicine as a topical therapy for skin problems such as acne and eczema (Čižmárová, B., et al. 2023), Sulfur contains antibacterial and anti-inflammatory properties, making it useful in the treatment of various illnesses, certain treatments, such as antibiotics and antifungal drugs, are also made with sulfur, despite its various uses, sulfur may be a sulfide (Asnaashari, S., et al. 2023, Niazi, P., et al. 2023), Sulfur is essential for the synthesis of proteins, chlorophyll, and amino acids in plants, the amount of sulfur in various sections of the plant varies, with leaves and seeds having the greatest quantities ((Saquee, F. S., et al. 2023, Saleem, S., et al. 2023), Sulfur deficiency can cause chlorosis, stunted growth, lower production, and poor seed quality (McCauley, A., et al. 2009).

Sulfur dioxide is emitted into the atmosphere when sulfur-containing fuels are burned (Perraud, V., et al. 2015), contributing to acid rain and other environmental hazards (Niazi, P., et al. 2023, Yang, H., et al. 2023). Finally, sulfur is a versatile element with several applications in business, agriculture, and medicine (Rai, M., et al. 2016), it is necessary for life, but it may also cause environmental issues, so initiatives to reduce sulfur emissions, and increase sulfur utilization in business and agriculture will be critical in the coming years, table 7, (Erisman, J. W., et al. 2007).

Table 1: Several macronutrients, their abundance on the Earth's crust, the principal form of abundance, and weight percentage in the Earth's crust by the year

Macronutrient	Element Symbol	Order of Abundance in Earth's Crust	Discovered by Year	Major Form of Abundance	Weight % in Earth's Crust
Oxygen	O	1	1774	Oxides	46.6
Silicon	Si	2	1824	Silicates	27.7
Aluminum	Al	3	1825	Silicates	8.1
Iron	Fe	4	Ancient	Oxides	5.0
Calcium	Ca	5	1808	Carbonates	3.6
Sodium	Na	6	1807	Chlorides	2.8
Potassium	K	7	1807	Silicates	2.6
Magnesium	Mg	8	1808	Silicates	2.1

Table 2: Summarizing the role, percentage, and deficiency symptoms of nitrogen in different parts of plants

Plant Part	Role of Nitrogen	Target cells	Percentage of Nitrogen	Deficiency Symptoms
Leaves	Essential for chlorophyll production of healthy green leaves, and photosynthesis	Mesophyll cells	2-4%	Yellowing of older leaves, stunted growth
Stems	Helps to produce proteins and enzymes, which are the building blocks of proteins, it is essential for the structural integrity of plants, including the stems.	Apical meristems, vascular tissue	0.1-0.5%	Stunted growth, weak stems
Roots	Essential for root growth and development, it is also a component of nucleic acids and DNA, which	Root tips, meristems	0.2-0.5%	Stunted growth, reduced root growth

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Volume-2 Issue-2 || April 2023 || PP. 268-279
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	play a critical role in cell division and growth.			
Flowers	Helps with flower, and seed production of amino acids, and proteins, which are essential for the development and growth of flowers.	Developing reproductive tissues	0.1-0.5%	Reduced flowering, small and immature flowers
Fruits	Aids in fruit development and ripening, it is also a component of amino acids, and proteins, which contribute to the flavor and nutritional value of fruits.	Developing reproductive tissues	0.1-0.5%	Reduced fruit size, delayed ripening

Table 3: Summarizing the role, percentage, and deficiency symptoms of phosphorus in different parts of plants

Plant Part	**Role of Phosphorus**	Target cells	**Percentage of Phosphorus**	**Deficiency Symptoms**
Leaves	Photosynthesis, energy storage and transfer, cell division, and elongation	Mesophyll cells	0.1 - 0.3%	Dark green or purple discoloration, necrosis, reduced growth, and yield
Stems	Energy storage, and transfer, cell division and elongation	Apical meristems, vascular tissue	0.1 - 0.3%	Reduced growth, thin stems, weak branches
Roots	Energy storage, and transfer, cell division and elongation, root development	Root tips, meristems	0.1 - 0.5%	Reduced growth, thin roots, poor development, increased susceptibility to diseases
Flowers	Energy transfer, flower development, seed production	Developing reproductive tissues	0.1 - 0.3%	Reduced flower production, poor seed set, decreased fertility
Fruits	Energy transfer, fruit development, ripening	Developing reproductive tissues	0.1 - 0.5%	Reduced fruit size, and quality, delayed maturation, increased susceptibility to diseases

Table 4: Summarizing the role, percentage, and deficiency symptoms of potassium in different parts of plants

Plant Part	**Role of Potassium**	Target cells	**Percentage of Potassium**	**Deficiency Symptoms**
Leaves	Regulates stomata, activates enzymes for photosynthesis, improves stress tolerance	Mesophyll cells	2-5%	Chlorosis (yellowing) and necrosis (death) along the edges of leaves, reduced growth and yield
Stem	Improves mechanical strength and resistance to diseases and pests	Apical meristems, vascular tissue	0.2-2%	Weak stems that easily break or bend, increased susceptibility to diseases and pests
Roots	Enhances water and nutrient uptake, improves root growth, and development	Root tips, meristems	0.5-5%	Reduced root growth and development, increased susceptibility to drought, and nutrient deficiencies
Flowers/Fruits	Improves flower/fruit formation and quality, enhances resistance to diseases and pests	Developing reproductive tissues	0.2-2%	Reduced flower/fruit formation and quality, increased susceptibility to diseases and pests

Table 5: Summarizing the role, percentage, and deficiency symptoms of calcium in different parts of plants

Part of Plant	**Role of Calcium**	Target cells	**Percentage of Calcium**	**Deficiency Symptoms**
Root	Cell growth and elongation, improving root system development	Mesophyll cells	0.1-5%	Reduced root growth, stunted plants, abnormal root tips

ISSN: 2583-4053
Volume-2 Issue-2 || April 2023 || PP. 268-279
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Stem	Enhancing cell wall structure and stability, activating enzymes	Apical meristems, vascular tissue	0.05-0.3%	Weak stems, reduced stem elongation, reduced transport of water and nutrients
Leaves	Activating K to control stomata, improving resistance, contributing to normal leaf development	Root tips, meristems	0.2-2.0%	Yellowing of leaves, black spots, abnormal leaf shape, and size
Flowers	Enhancing pollen tube growth, promoting fruit development	Developing reproductive tissues	0.01-0.05%	Reduced fruit set, reduced pollen viability
Fruits	Regulating fruit ripening, improving fruit quality	Developing reproductive tissues	0.01-0.2%	Fruit cracking, blossom-end rot, reduced fruit shelf-life

Table 6: Summarizing the role, percentage, and deficiency symptoms of magnesium in different parts of plants

Plant Part	**Role of Magnesium**	Target cells	**Percentage of Magnesium**	**Deficiency Symptoms**
Leaves	Component of chlorophyll; aids in photosynthesis	Mesophyll cells	1-2%	Yellowing between veins; interveinal chlorosis
Stem	Aids in the transport of nutrients and water	All cells	0.2-0.4%	Stunted growth; chlorosis
Roots	Aids in the uptake and transport of nutrients	All cells	0.1-0.2%	Stunted growth; chlorosis
Seeds	Component of enzymes involved in seed development	Developing reproductive tissues	0.05-0.2%	Reduced seed production; poor germination

Table 7: Summarizing the role, percentage, and deficiency symptoms of sulfur in different parts of plants

Plant Part	**Role of Sulfur**	**Target cells**	**Percentage of Sulfur**	**Deficiency Symptoms**
Leaves	Essential for the synthesis of chlorophyll and amino acids	Mesophyll cells	0.3-0.5%	Chlorosis, stunted growth, reduced yield
Seeds	Important for the synthesis of proteins and oils	All cells	0.2-0.5%	Reduced seed size and quality
Roots	Necessary for the uptake of other nutrients	All cells	0.1-0.2%	Stunted growth, reduced root development
Flowers	Required for the development of reproductive structures	Developing reproductive tissues	0.1-0.2%	Reduced flowering, poor seed set

III. CONCLUSION

Macronutrients are essential for plant growth, and development, and can have an impact on all phases of a plant's existence, however, an excess or deficiency of these nutrients can negatively impact a plant's overall performance, highlighting the need for tight regulation of its cellular status, research has shown that over 60% of the world's population, or 6.1 billion people, suffer from malnutrition, with calcium, magnesium, and copper deficiencies being common in both developed and developing countries, this shortage of minerals in sources such as crops, food, and water underscores the importance of tight regulation of their cellular status, bio-fortification of crops with certain macronutrients may aid in the alleviation of mineral shortages, and the reduction of agricultural production loss due to various stressors, thereby assisting in feeding the world's rising population.

CONFLICTS OF INTEREST

Authors have declared that no competing interests exist.

REFERENCES

[1] Abbas, F., Siddique, T., Fan, R., & Azeem, M. (2023). Role of Gypsum in Conserving Soil Moisture Macronutrients Uptake and Improving Wheat Yield in the Rainfed Area. *Water*, *15*(6), 1011.
[2] Abdelsattar, A. M., Elsayed, A., El-Esawi, M. A., & Heikal, Y. M. (2023). Enhancing Stevia rebaudiana growth and yield through exploring beneficial plant-

ISSN: 2583-4053
Volume-2 Issue-2 || April 2023 || PP. 268-279
https://doi.org/10.55544/jrasb.2.2.38

microbe interactions and their impact on the underlying mechanisms and crop sustainability. *Plant Physiology and Biochemistry*, 107673.
[3] Ahmad, N., Jiang, Z., Zhang, L., Hussain, I., & Yang, X. (2023). Insights on Phytohormonal Crosstalk in Plant Response to Nitrogen Stress: A Focus on Plant Root Growth and Development. *International Journal of Molecular Sciences*, *24*(4), 3631.
[4] Ahmed, M. E., Bounouira, H., Abbo, M. A., Amsil, H., Didi, A., & Aarab, I. (2023). Utilizing the k0-IAEA program to determine rare earth elements in soil samples from gold-mining areas in Sudan. *Journal of Radioanalytical and Nuclear Chemistry*, 1-15.
[5] Alam, I., Zhang, H., Du, H., Rehman, N. U., Manghwar, H., Lei, X., & Ge, L. (2023). Bioengineering Techniques to Improve Nitrogen Transformation and Utilization: Implications for Nitrogen Use Efficiency and Future Sustainable Crop Production. *Journal of Agricultural and Food Chemistry*.
[6] Ali, V., Rashid, A., Kumar, D., & Vyas, D. (2023). Stage-specific metabolomics suggests a trade-off between primary and secondary metabolites for nutritional advantage in Lepidium latifolium L. *Food Chemistry*, 136035.
[7] Amareh, R., Kaviani, B., Sedaghathoor, S., & Allahyari, M. S. (2023). Assessment of some urban ornamental plants in southern Iran revealed that they choose one of the two enzymatic or non-enzymatic antioxidants defensive strategies against heavy metals.
[8] Amtmann, A., Troufflard, S., & Armengaud, P. (2008). The effect of potassium nutrition on pest and disease resistance in plants. *Physiologia plantarum*, *133*(4), 682-691.
[9] Asnaashari, S., Kazemnezhad, M., Masoud, F., & Javadzadeh, Y. (2023). An overview on the anti-acne properties of herbal essential oils. *Journal of Herbal Medicine*, 100642.
[10] Aversa, R., Petrescu, R. V., Apicella, A., & Petrescu, F. I. (2016). The basic elements of life's. *American Journal of Engineering and Applied Sciences*, *9*(4), 1189-1197.
[11] Aydin, I., & Uzun, F. (2005). Nitrogen and phosphorus fertilization of rangelands affects yield, forage quality and the botanical composition. *European Journal of Agronomy*, *23*(1), 8-14.
[12] Basu, U., & Parida, S. K. (2023). The developmental dynamics in cool season legumes with focus on chickpea. *Plant Molecular Biology*, 1-19.
[13] Bhattarai, S. P., Pendergast, L., & Midmore, D. J. (2006). Root aeration improves yield and water use efficiency of tomato in heavy clay and saline soils. *Scientia horticulturae*, *108*(3), 278-288.
[14] Broadley, M., Brown, P., Cakmak, I., Rengel, Z., & Zhao, F. (2012). Function of nutrients: micronutrients. In *Marschner's mineral nutrition of higher plants* (pp. 191-248). Academic Press.
[15] Brosnan, J. T., & Brosnan, M. E. (2006). The sulfur-containing amino acids: an overview. *The Journal of nutrition*, *136*(6), 1636S-1640S.
[16] Buchowski, M. S. (2015). Calcium in the context of dietary sources and metabolism.
[17] Cakmak, I., & Yazici, A. M. (2010). Magnesium: a forgotten element in crop production. *Better crops*, *94*(2), 23-25.
[18] Candanosa, R. M. (2017). Growing green on the red planet. *ChemMatters*, *2016*.
[19] Castro, V., Carpena, M., Fraga-Corral, M., Lopez-Soria, A., Garcia-Perez, P., Barral-Martinez, M., & Prieto, M. A. (2023). Sulfur-containing compounds from plants. In *Natural Secondary Metabolites: From Nature, Through Science, to Industry* (pp. 363-402). Cham: Springer International Publishing.
[20] Chathyushya, K. B., Hemalatha, R., Ananthan, R., Devraj, J. P., Banjara, S. K., Alimelu, M., & Nitasha, B. (2023). Macronutrient composition of term and preterm human milk of different socio economic groups. *Prostaglandins, Leukotrienes and Essential Fatty Acids*, 102571.
[21] Chen, B., Ren, C., Wang, C., Duan, J., Reis, S., & Gu, B. (2023). Driving forces of nitrogen use efficiency in Chinese croplands on county scale. *Environmental Pollution*, *316*, 120610.
[22] Childs, P. E. (1998). From hydrogen to meitnerium: naming the chemical elements. *Chemical nomenclature*, 27-66.
[23] Čižmárová, B., Hubková, B., Tomečková, V., & Birková, A. (2023). Flavonoids as Promising Natural Compounds in the Prevention and Treatment of Selected Skin Diseases. *International Journal of Molecular Sciences*, *24*(7), 6324.
[24] Collins, A., Møller, P., Gajski, G., Vodenková, S., Abdulwahed, A., Anderson, D., & Azqueta, A. (2023). Measuring DNA modifications with the comet assay: A compendium of protocols. *Nature Protocols*, 1-61.
[25] Corti, F., Festa, M., & Szabo, I. (2023). Mitochondria–Chloroplast Cross Talk: A Possible Role for Calcium and Reactive Oxygen Species? *Bioelectricity*, *5*(1), 39-46.
[26] Das, S. K., Avasthe, R. K., & Yadav, A. (2017). Secondary and micronutrients: deficiency symptoms and management in organic farming.
[27] De Freitas, Sergio Tonetto, and Elizabeth J. Mitcham. "Factors involved in fruit calcium deficiency disorders." *Horticultural reviews* 40 (2012): 107-146.
[28] De Vries, W., Dobbertin, M. H., Solberg, S., Van Dobben, H. F., & Schaub, M. (2014). Impacts of acid deposition, ozone exposure and weather conditions on forest ecosystems in Europe: an overview. *Plant and Soil*, *380*, 1-45.
[29] Delgado, A., Gonçalves, S., & Romano, A. (2023). Mediterranean Diet: The Role of Phenolic Compounds from Aromatic Plant Foods. *Foods*, *12*(4), 840.
[30] Daramola, D. A., & Hatzell, M. C. (2023). Energy Demand of Nitrogen and Phosphorus Based Fertilizers

ISSN: 2583-4053
Volume-2 Issue-2 || April 2023 || PP. 268-279
https://doi.org/10.55544/jrasb.2.2.38

and Approaches to Circularity. *ACS Energy Letters*, *8*(3), 1493-1501.

[31] Desmidt, E., Ghyselbrecht, K., Zhang, Y., Pinoy, L., Van der Bruggen, B., Verstraete, W., & Meesschaert, B. (2015). Global phosphorus scarcity and full-scale P-recovery techniques: a review. *Critical Reviews in Environmental Science and Technology*, *45*(4), 336-384.

[32] Diwakar, A. K., Yadav, J., Patel, K., Prajapati, S. K., Vandana, V. J., & Soni, R. L. (2023). Study of Physico-chemical and Nutrient Status of the Soil in Chiraigaon Block, Varanasi District, Uttar Pradesh, India. *International Journal of Plant & Soil Science*, *35*(6), 79-86.

[33] Duruibe, J. O., Ogwuegbu, M. O. C., & Egwurugwu, J. N. (2007). Heavy metal pollution and human biotoxic effects. *International Journal of physical sciences*, *2*(5), 112-118.

[34] Elango, D., Devi, K. D., Jeyabalakrishnan, H. K., Rajendran, K., Haridass, V. K. T., Dharmaraj, D., ... & Wang, X. (2022). Agronomic, breeding, and biotechnological interventions to mitigate heavy metal toxicity problems in agriculture. *Journal of Agriculture and Food Research*, *10*, 100374.

[35] Erisman, J. W., Bleeker, A., Galloway, J., & Sutton, M. S. (2007). Reduced nitrogen in ecology and the environment. *Environmental pollution*, *150*(1), 140-149.

[36] Farooq, M., Wahid, A., Kobayashi, N. S. M. A., Fujita, D. B. S. M. A., & Basra, S. M. A. (2009). Plant drought stress: effects, mechanisms and management. *Sustainable agriculture*, 153-188.

[37] Forsen, S. T. U. R. E., & Kordel, J. O. H. A. N. (1994). Calcium in biological systems. *Bioinorganic chemistry*, 107-166.

[38] Freire, M. Á. (2023). The origins of photosynthetic systems: Clues from the phosphorus and sulphur chemical scenarios. *Biosystems*, *226*, 104873.

[39] Frieden, E. (1972). The chemical elements of life. *Scientific American*, *227*(1), 52-64.

[40] Gleeson, M., Nieman, D. C., & Pedersen, B. K. (2004). Exercise, nutrition and immune function. *Journal of sports sciences*, *22*(1), 115-125.

[41] Golden, M. H. (1995). Specific deficiencies versus growth failure: type I and type II nutrients. *SCN news*, *12*(10), 10-4.

[42] Golebiowska-Paluch, G., & Dyda, M. (2023). The Genome Regions Associated with Abiotic and Biotic Stress Tolerance, as Well as Other Important Breeding Traits in Triticale. *Plants*, *12*(3), 619.

[43] Graham, M., Clark, C., Scherer, A., Ratner, M., Keen, C., Graham, M. T., & Keen, C. L. (2023). An Analysis of the Nutritional Adequacy of Mass-Marketed Vegan Recipes. *Cureus*, *15*(4).

[44] Gu, M., Chen, A., Sun, S., & Xu, G. (2016). Complex regulation of plant phosphate transporters and the gap between molecular mechanisms and practical application: what is missing? *Molecular Plant*, *9*(3), 396-416.

[45] Hallfrisch, J., & Muller, D. C. (1993). Does diet provide adequate amounts of calcium, iron, magnesium, and zinc in a well-educated adult population? *Experimental gerontology*, *28*(4-5), 473-483.

[46] Hasanuzzaman, M., Bhuyan, M. B., Nahar, K., Hossain, M. S., Mahmud, J. A., Hossen, M. S., & Fujita, M. (2018). Potassium: a vital regulator of plant responses and tolerance to abiotic stresses. *Agronomy*, *8*(3), 31.

[47] Hawkesford, M. J., Cakmak, I., Coskun, D., De Kok, L. J., Lambers, H., Schjoerring, J. K., & White, P. J. (2023). Functions of macronutrients. In *Marschner's Mineral Nutrition of Plants* (pp. 201-281). Academic press.

[48] Hedrich, R. (2012). Ion channels in plants. *Physiological reviews*, *92*(4), 1777-1811.

[49] Hong-Bo, S., Li-Ye, C., Ming-An, S., Shi-Qing, L., & Ji-Cheng, Y. (2008). Bioengineering plant resistance to abiotic stresses by the global calcium signal system. *Biotechnology advances*, *26*(6), 503-510.

[50] Huxley, H. E. (1969). The Mechanism of Muscular Contraction: Recent structural studies suggest a revealing model for cross-bridge action at variable filament spacing. *Science*, *164*(3886), 1356-1366.

[51] Islam, M., Akash, S., Jony, M. H., Nowrin, F. T., Rahman, M., Rauf, A., & Thiruvengadam, M. (2023). Exploring the potential function of trace elements in human health: a therapeutic perspective. *Molecular and Cellular Biochemistry*, 1-31.

[52] Jacoby, R., Peukert, M., Succurro, A., Koprivova, A., & Kopriva, S. (2017). The role of soil microorganisms in plant mineral nutrition—current knowledge and future directions. *Frontiers in plant science*, *8*, 1617.

[53] Jackson, P. J., Hitchcock, A., Brindley, A. A., Dickman, M. J., & Hunter, C. N. (2023). Absolute quantification of cellular levels of photosynthesis-related proteins in Synechocystis sp. PCC 6803. *Photosynthesis Research*, *155*(3), 219-245.

[54] Jha, S., & Yadav, A. (2023). Plants response to SO2 or acid deposition. In *Plants and their Interaction to Environmental Pollution* (pp. 99-108). Elsevier.

[55] Joshi, H., Bisht, N., & Chauhan, P. S. (2023). Regulation of Phytohormonal Signaling by Nutrients in Plant. *Plant Ionomics: Sensing, Signaling, and Regulation*, 191-208.

[56] Karabulut, F., Shameem, N., Shafi, N., Parray, J. A., Hashem, A., & Abd-Allah, E. F. (2023). Over View of Symbiosis Mechanisms and Soil Quality Management Practices to Combat Environmental Changes. In *Climate Change and Microbiome Dynamics: Carbon Cycle Feedbacks* (pp. 245-270). Cham: Springer International Publishing.

[57] Karthika, K. S., Rashmi, I., & Parvathi, M. S. (2018). Biological functions, uptake and transport of essential nutrients in relation to plant growth. *Plant nutrients and abiotic stress tolerance*, 1-49.

ISSN: 2583-4053
Volume-2 Issue-2 || April 2023 || PP. 268-279
https://doi.org/10.55544/jrasb.2.2.38

[58] Keita, D. S., Keita, M., Moctar, T., & Patel, H. (2023). Physico-chemical parameters, macronutrients and micronutrients evaluation in the soil of Trenabougou, rural commune of Siby, Mali. *African Journal of Agricultural Research*, *19*(1), 24-32.
[59] Kirkby, E. A. (2023). Introduction, definition, and classification of nutrients. In *Marschner's Mineral Nutrition of Plants* (pp. 3-9). Academic press.
[60] Kruse, O., Rupprecht, J., Mussgnug, J. H., Dismukes, G. C., & Hankamer, B. (2005). Photosynthesis: a blueprint for solar energy capture and biohydrogen production technologies. *Photochemical & Photobiological Sciences*, *4*(12), 957-970.
[61] Kumar, S., Korra, T., Thakur, R., Arutselvan, R., Kashyap, A. S., Nehela, Y., & Keswani, C. (2023). Role of Plant Secondary Metabolites in Defence and Transcriptional Regulation in Response to Biotic Stress. *Plant Stress*, 100154.
[62] Kumari, S., Kumar, P., Kiran, S., Kumari, S., & Singh, A. (2023). Characterization of culture condition dependent, growth responses of phosphate solubilizing bacteria (Bacillus subtilis DR2) on plant growth promotion of Hordeum vulgare. *Vegetos*, 1-11.
[63] Kumari, A., Das, P., Parida, A. K., & Agarwal, P. K. (2015). Proteomics, metabolomics, and ionomics perspectives of salinity tolerance in halophytes. *Frontiers in Plant Science*, *6*, 537.
[64] Kutney, G. (2023). *Sulfur: history, technology, applications and industry*. Elsevier.
[65] Ledda, C., & Fiore, M. (2013). Magnesium (Mg). *Health Effects of Metals and Related Substances in Drinking Water*, *68*.
[66] Leghari, S. J., Wahocho, N. A., Laghari, G. M., HafeezLaghari, A., MustafaBhabhan, G., HussainTalpur, K., & Lashari, A. A. (2016). Role of nitrogen for plant growth and development: A review. *Advances in Environmental Biology*, *10*(9), 209-219.
[67] Li, M., Guo, S., Xu, Y., Meng, Q., Li, G., & Yang, X. (2014). Glycine betaine-mediated potentiation of HSP gene expression involves calcium signaling pathways in tobacco exposed to NaCl stress. *Physiologia plantarum*, *150*(1), 63-75.
[68] Li, X., Huang, L., Zhang, Y., Ouyang, Z., Hong, Y., Zhang, H., & Song, F. (2014). Tomato SR/CAMTA transcription factors SlSR1 and SlSR3L negatively regulate disease resistance response and SlSR1L positively modulates drought stress tolerance. *BMC plant biology*, *14*(1), 1-19.
[69] Liu, C., Lyu, W., Zhao, W., Zheng, F., & Lu, J. (2023). Exploratory research on influential factors of China's sulfur dioxide emission based on symbolic regression. *Environmental Monitoring and Assessment*, *195*(1), 41.
[70] Liao, Z., Zhang, J., Wang, J., Yan, T., Xu, F., Wu, B., & Jia, Y. (2019). The anti-nephritic activity of a polysaccharide from okra (Abelmoschus esculentus (L.) Moench) via modulation of AMPK-Sirt1-PGC-1α signaling axis mediated anti-oxidative in type 2 diabetes model mice. *International journal of biological macromolecules*, *140*, 568-576.
[71] Liu, J., Cai, H., Chen, S., Pi, J., & Zhao, L. (2023). A Review on Soil Nitrogen Sensing Technologies: Challenges, Progress and Perspectives. *Agriculture*, *13*(4), 743.
[72] Mahboob, W., Yang, G., & Irfan, M. (2023). Crop nitrogen (N) utilization mechanism and strategies to improve N use efficiency. *Acta Physiologiae Plantarum*, *45*(4), 52.
[73] Malhotra, H., Sharma, S., & Pandey, R. (2018). Phosphorus nutrition: plant growth in response to deficiency and excess. *Plant nutrients and abiotic stress tolerance*, 171-190.
[74] Marschner, H. (Ed.). (2011). *Marschner's mineral nutrition of higher plants*. Academic press.
[75] McCauley, A., Jones, C., & Jacobsen, J. (2009). Plant nutrient functions and deficiency and toxicity symptoms. *Nutrient management module*, *9*, 1-16.
[76] Mihai, R. A., Melo Heras, E. J., Terán Maza, V. A., Espinoza Caiza, I. A., Pinto Valdiviezo, E. A., & Catana, R. D. (2023). The Panoramic View of Ecuadorian Soil Nutrients (Deficit/Toxicity) from Different Climatic Regions and Their Possible Influence on the Metabolism of Important Crops. *Toxics*, *11*(2), 123.
[77] Miller, G. D., Jarvis, J. K., & McBean, L. D. (2001). The importance of meeting calcium needs with foods. *Journal of the American College of Nutrition*, *20*(2), 168S-185S.
[78] Młodzińska, E., & Zboińska, M. (2016). Phosphate uptake and allocation–a closer look at Arabidopsis thaliana L. and Oryza sativa L. *Frontiers in Plant Science*, *7*, 1198.
[79] Mohammed, N. A. (2016). *Chemical Analysis of Grewia Tenax Fruits* (Doctoral dissertation, Sudan University for Science and Technology).
[80] Mohammadnezhadostad, F., Shojaei, D., & Ghazipoor, H. (2023). Investigation of Nursing, And Medical Services In Patients with Diabetes, Abdominal Pain and High Blood Pressure. *Journal of Pharmaceutical Negative Results*, *14*(2).
[81] Murphy, P. J. (2011). A 2× 2 conceptual foundation for entrepreneurial discovery theory. *Entrepreneurship Theory and Practice*, *35*(2), 359-374.
[82] Mushtaq, N. U., Alghamdi, K. M., Saleem, S., Tahir, I., Bahieldin, A., Henrissat, B., & Hakeem, K. R. (2023). Exogenous zinc mitigates salinity stress by stimulating proline metabolism in proso millet (Panicum miliaceum L.). *Frontiers in Plant Science*, *14*.
[83] Mustafa, A., Zulfiqar, U., Mumtaz, M. Z., Radziemska, M., Haider, F. U., Holatko, J., & Brtnicky, M. (2023). Nickel (Ni) phytotoxicity and detoxification mechanisms: A review. *Chemosphere*, 138574.
[84] Moustafa-Farag, M., Elkelish, A., Dafea, M., Khan, M., Arnao, M. B., Abdelhamid, M. T., & Ai, S. (2020). Role of melatonin in plant tolerance to soil

ISSN: 2583-4053
Volume-2 Issue-2 || April 2023 || PP. 268-279
https://doi.org/10.55544/jrasb.2.2.38

stressors: salinity, pH and heavy metals. *Molecules*, *25*(22), 5359.

[85] Niazi, P., Alimyar, O., Azizi, A., Monib, A. W., & Ozturk, H. (2023). People-plant Interaction: Plant Impact on Humans and Environment. Journal of Environmental and Agricultural Studies, 4(2), 01-07.

[86] Niazi, P., Monib, A. W., Ozturk, H., Mansoor, M., Azizi, A., & Hassand, M. H. (2023). Review on Surface Elements and Bacterial Biofilms in Plant-Bacterial Associations. *Journal for Research in Applied Sciences and Biotechnology*, *2*(1), 204-214.

[87] Niazi, P., Monib, A. W., & Azizi, A. (2023). A Review on Plants and Plant/Microbial Systems in Reducing Exposure. *Journal for Research in Applied Sciences and Biotechnology*, *2*(2), 1-7.

[88] Nover, L. U. T. Z., Scharf, K. D., & Neumann, D. I. E. T. E. R. (1989). Cytoplasmic heat shock granules are formed from precursor particles and are associated with a specific set of mRNAs. *Molecular and cellular biology*, *9*(3), 1298-1308.

[89] Oosterhuis, D. M., Loka, D. A., Kawakami, E. M., & Pettigrew, W. T. (2014). The physiology of potassium in crop production. *Advances in agronomy*, *126*, 203-233.

[90] Osei, E., Jafri, S. H., Gassman, P. W., Saleh, A., & Gallego, O. (2023). Climate Change Impacts on Surface Runoff and Nutrient and Sediment Losses in Buchanan County, Iowa. *Agriculture*, *13*(2), 470.

[91] Ozturk, H., Niazi, P., Mansoor, M., Monib, A. W., Alikhail, M., & Azizi, A. (2023). The Function of Zinc in Animal, Plant, and Human Nutrition. Journal for Research in Applied Sciences and Biotechnology, 2(2), 35–43. https://doi.org/10.55544/jrasb.2.2.6

[92] Pathan, M. F. (2022). Hypomagnesemia and diabetes mellitus: a bidirectional situation. *BIRDEM Medical Journal*, *12*(3), 172-176.

[93] Perraud, V., Horne, J. R., Martinez, A. S., Kalinowski, J., Meinardi, S., Dawson, M. L., & Finlayson-Pitts, B. J. (2015). The future of airborne sulfur-containing particles in the absence of fossil fuel sulfur dioxide emissions. *Proceedings of the National Academy of Sciences*, *112*(44), 13514-13519.

[94] Pohl, H. R., Wheeler, J. S., & Murray, H. E. (2013). Sodium and potassium in health and disease. *Interrelations between essential metal ions and human diseases*, 29-47.

[95] Pozharskii, A. F., Katritzky, A. R., & Soldatenkov, A. T. (2011). *Heterocycles in life and society* (pp. 144-146). Chichester: Wiley.

[96] Prathap, V., Kumar, A., Maheshwari, C., & Tyagi, A. (2022). Phosphorus homeostasis: Acquisition, sensing, and long-distance signaling in plants. *Molecular Biology Reports*, *49*(8), 8071-8086.

[97] Quattrini, S., Pampaloni, B., & Brandi, M. L. (2016). Natural mineral waters: chemical characteristics and health effects. *Clinical Cases in Mineral and Bone Metabolism*, *13*(3), 173.

[98] Rai, M., Ingle, A. P., & Paralikar, P. (2016). Sulfur and sulfur nanoparticles as potential antimicrobials: from traditional medicine to nanomedicine. *Expert review of anti-infective therapy*, *14*(10), 969-978.

[99] Ramesh, B., Saravanan, A., Kumar, P. S., Yaashikaa, P. R., Thamarai, P., Shaji, A., & Rangasamy, G. (2023). A review on algae biosorption for the removal of hazardous pollutants from wastewater: Limiting factors, prospects and recommendations. *Environmental Pollution*, 121572.

[100] Raschke, K. (1975). Stomatal action. *Annual Review of Plant Physiology*, *26*(1), 309-340.

[101] Raven, J. A. (2023). Avoiding and Allowing Apatite precipitation in Oxygenic Photolithotrophs. *New Phytologist*.

[102] Ray, P. K. (2023). Nutrition, Fertilization and Irrigation. In *Jackfruit: Botany, Production and Uses* (pp. 158-194). GB: CABI.

[103] Rizhsky, L., Liang, H., & Mittler, R. (2002). The combined effect of drought stress and heat shock on gene expression in tobacco. *Plant physiology*, *130*(3), 1143-1151.

[104] Rosen, C., Hutchison, B., Tong, C., Becker, R., Sharma, V., Ford, J., & Nesser, S. (2023). Growing garlic in Minnesota.

[105] Roy-Bolduc, A., & Hijri, M. (2011). The use of mycorrhizae to enhance phosphorus uptake: a way out the phosphorus crisis. *J. Biofertil. Biopestici*, *2*(104), 1-5.

[106] Saha, B., Reddy, K. M., Saha, S., Fatima, A., & Solankey, S. S. (2023). Nutritional Stress Management in Vegetable Crops Under Changing Climate Scenario. In *Advances in Research on Vegetable Production Under a Changing Climate Vol. 2* (pp. 85-108). Cham: Springer International Publishing.

[107] Saleem, S., Mushtaq, N. U., Rasool, A., Shah, W. H., Tahir, I., & Rehman, R. U. (2023). Plant nutrition and soil fertility: physiological and molecular avenues for crop improvement. In *Sustainable Plant Nutrition* (pp. 23-49). Academic Press.

[108] Saquee, F. S., Diakite, S., Kavhiza, N. J., Pakina, E., & Zargar, M. (2023). The Efficacy of Micronutrient Fertilizers on the Yield Formulation and Quality of Wheat Grains. *Agronomy*, *13*(2), 566.

[109] Schoumans, O. F., Chardon, W. J., Bechmann, M. E., Gascuel-Odoux, C., Hofman, G., Kronvang, B.,& Dorioz, J. M. (2014). Mitigation options to reduce phosphorus losses from the agricultural sector and improve surface water quality: a review. *Science of the total environment*, *468*, 1255-1266.

[110] Shah, S. H., Islam, S., & Mohammad, F. (2022). Sulphur as a dynamic mineral element for plants: a review. *Journal of Soil Science and Plant Nutrition*, *22*(2), 2118-2143.

[111] Shekade, S. V., Shirolkar, S. V., Deshkar, S. S., & Giram, P. S. (2023). Phytochemical, Pharmacognostic, and Pharmacological Aspects of Ricinus Communis

ISSN: 2583-4053
Volume-2 Issue-2 || April 2023 || PP. 268-279
https://doi.org/10.55544/jrasb.2.2.38

Seed Oil: An Overview. *The Natural Products Journal*, *13*(3), 31-47.
[112] Singh, S. K., Sahoo, J. P., Saikia, S., Pradhan, P., Mishra, A. P., Behera, L., & Panda, N. (2023). Biofortification of Rice (Oryza sativa L.). In *Biofortification in Cereals: Progress and Prospects* (pp. 149-172). Singapore: Springer Nature Singapore.
[113] Soetan, K. O., Olaiya, C. O., & Oyewole, O. E. (2010). The importance of mineral elements for humans, domestic animals and plants: A review. *African journal of food science*, *4*(5), 200-222.
[114] Stein, L. Y., & Klotz, M. G. (2016). The nitrogen cycle. *Current Biology*, *26*(3), R94-R98.
[115] Traber, M. G., & Cross, C. (2023). Alpha-Tocopherol from people to plants is an essential cog in the metabolic machinery. *Antioxidants and Redox Signaling*, (JA).
[116] Tariq, A., Zeng, F., Graciano, C., Ullah, A., Sadia, S., Ahmed, Z., & Zhang, Z. (2023). Regulation of Metabolites by Nutrients in Plants. *Plant Ionomics: Sensing, Signaling, and Regulation*, 1-18.
[117] Tränkner, M., Jákli, B., Tavakol, E., Geilfus, C. M., Cakmak, I., Dittert, K., & Senbayram, M. (2016). Magnesium deficiency decreases biomass water-use efficiency and increases leaf water-use efficiency and oxidative stress in barley plants. *Plant and Soil*, *406*, 409-423.
[118] Tripathi, D. K., Singh, V. P., Chauhan, D. K., Prasad, S. M., & Dubey, N. K. (2014). Role of macronutrients in plant growth and acclimation: recent advances and future prospective. *Improvement of Crops in the Era of Climatic Changes: Volume 2*, 197-216.
[119] Uchida, R. (2000). Essential nutrients for plant growth: nutrient functions and deficiency symptoms. *Plant nutrient management in Hawaii's soils*, *4*, 31-55.
[120] Wan, Z., Hu, X., Li, C., Zhang, J., Wang, Q., Fang, L., & Sun, D. (2023). Simultaneous oxidation and absorption of nitric oxide and sulfur dioxide by peroxymonosulfate activated by bimetallic metal-organic frameworks. *Journal of Environmental Chemical Engineering*, *11*(2), 109417.
[121] Wang, Y., Zhang, X., Zhang, W., Peng, M., Tan, G., Qaseem, M. F., & Wu, A. M. (2023). Physiological and transcriptomic responses to magnesium deficiency in Neolamarckia Cadamba. *Plant Physiology and Biochemistry*, 107645.
[122] Waraich, E. A., Ahmad, R., & Ashraf, M. Y. (2011). Role of mineral nutrition in alleviation of drought stress in plants. *Australian Journal of Crop Science*, *5*(6), 764-777.
[123] Webb, S. (2023). The World Itself. In *Around the World in 80 Ways: Exploring Our Planet Through Maps and Data* (pp. 7-38). Cham: Springer International Publishing.
[124] Weng, W., Zhang, W., Lin, H., Chi, X., & Zhong, S. (2023). Fixing sulfur dioxide by feeding calcine oxide into the rotary volatilization kiln in zinc smelting plant. *Environmental Science and Pollution Research*, 1-10.
[125] Wevar Oller, A. L., Vezza, M. E., Talano, M. A., & Agostini, E. (2023). Grain and Forage Legumes in an Arsenic-Polluted Agricultural Scenario. *Journal of Plant Growth Regulation*, 1-22.
[126] Wiedenhoeft, A. C. (2006). *Plant nutrition*. Infobase Publishing.
[127] Williams, C. J., & Yavitt, J. B. (2003). Botanical composition of peat and degree of peat decomposition in three temperate peatlands. *Ecoscience*, *10*(1), 85-95.
[128] Xu, Q., Cao, K., Dai, J., Zhu, Y., & Dai, Y. (2023). Nonlinear Effects of Eco-Industrial Parks on Sulfur Dioxide and Carbon Dioxide Emissions—Estimation Based on Nonlinear DID. *Sustainability*, *15*(3), 1988.
[129] Yamano, A., Kubo, T., Chujo, F., Yamashita, N., Mukai, T., Morishita, M., & Sakai, T. (2023). Li pre-doping technique using perforated electrodes for the cells with a rubber-derived sulfur composite cathode. *Journal of Power Sources*, *556*, 232448.
[130] Yang, H., Bai, J., Zhou, T., Zhou, C., Xie, C., Zhang, Y., & Zhou, B. (2023). Electrochemical coupling conversion of sulfur-containing gaseous waste to treasure: A key review. *Applied Catalysis A: General*, *654*, 119085.
[131] Yang, T., Peng, H., Whitaker, B. D., & Jurick, W. M. (2013). Differential expression of calcium/calmodulin-regulated SlSRs in response to abiotic and biotic stresses in tomato fruit. *Physiologia plantarum*, *148*(3), 445-455.
[132] Yin, R., Zhu, S., Lu, T., Zhang, Q., Lin, D., Jin, H., & Lv, J. J. (2023). Nitrogen, sulfur, and oxygen tri-doped carbon nanosheets as efficient multifunctional electrocatalysts for Zn-air batteries and water splitting. *International Journal of Hydrogen Energy*.